Software-based Projector Sharing Research

Myungcheol Doo and Chih-Sung Wu (Andy) Wu
College of Computing
Georgia Institute of Technology
Atlanta, GA 30332
{mcdoo, andywu}@cc.gatech.edu

ABSTRACT
In this paper we propose a way of sharing image for supporting occasional meetings. Our main idea is that the sharing information occurs across public displays that users can easily access and interact with. To do this, we designed and implemented user-friendly software.

Author Keywords
Sharing, Projector, Display, Ubiquitous Computing, CSCW

ACM Classification Keywords
H.5.3 Group and Organization Interfaces: Compuer-supported cooperative work

INTRODUCTION
The idea of sharing information through a projector increases efficiency of group activities. However, sometimes switching between laptops takes a long time or needs to be manipulated to adjust laptop's resolution. Those things might hinder or delay ongoing conversation. Thus, there are needs to share what the user sees on a public display without delaying. Also, there are lots of expensive projectors or wall displays that are idle. If we can create a procedure that people can follow and build devices to share information, the rate of usages will increase. Because we believe that information sharing should be easy for a group of users and the administration of information sharing should be easy and large displays or projectors are expensive, we should try to use the most of them.

In the previous project, we developed software that allows a user to share his/her screen with others through a projector. Unlike the traditional way, which is plugging/unplugging a VGA cable, users install software and click an icon to share their screen. We expect that this software will encourage people to share their screen more frequently in a meeting. In this project, we will do user test to verify our solution.

RELATED WORK
Planex Communication's GW-AP54PR [1] is a user - friendly projecting device which turns a user's project into a wireless device so that any laptop or desktop computers can easily send VGA signal to the projector through Wireless and Ethernet environment. GW-AP54PR has almost similar functions that we present here. Users can instantly project user's screen to the projector within just one click. Also it supports multi-users to switch user's computer screen to projector without moving the computer to the projector and switch a VGA cable.

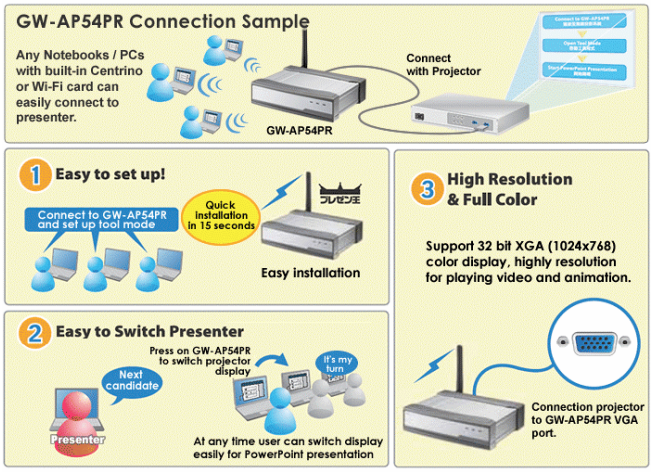

Figure 1. GW-AP54PR connection example

Besides Planex's device, Stanford University presented an Interactive Room (iRoom) [2]. The iRoom contains three touch sensitive displays along the sidewall and a display that was designed to look like a standard conference-room table. In the iRoom users can do move data, that is, users in the room are able to move data among the various visualization applications that run on screens in the room and on laptops or PDAs that are brought into the workspace. However, for users who want just sharing images the iRoom project is too big to use.

The Dynamo system [3] has been designed as a large publicly accessible interactive surface that allows people to gather around, share, display, and exchange media with others. The surface provides a multi cursor environment with each interaction point being represented by a color-coded pointer, called telepointer. Users take control of these

telepointers to interact with the surface. Dynamo surface is more than sharing display. It is designed for exchange digital media with others.

Single display groupware was developed to support shoulder-to-shoulder collaboration on a large display with multiple input points. Such systems allow multiple users to simultaneously interact with shared applications. Early examples include Cognoter [4] and MMM [5]. More recently, the Pebbles system [6] has explored how PDAs can provide concurrent input to a shared display. Similarly, Kidpad [7] supports multi-mice input with a view to promoting collaboration within the classroom.

SOLUTION

We intend to build software that can send the laptop screen to a projector connected to . We expect an application with one-click sharing function will help users work more efficiently using projectors.

User Scenario

Thad was teaching CS 7470 using a projector. He showed a website to his students. But one student found another interesting website, and he wanted to showed it to the class, too. However, he could not show the website from his seat. Therefore, he spoke out the address of the website to Thad and asked Thad to show it to the class.

System Setup

We construct a prototype of sharing a projector and created a software application for sharing images via Wireless and Ethernet environment. Figure 2 shows how the system architecture consists of. A projector, which stands for a public display that users want to use for sharing images, is connected to a server computer through a VGA cable. A server computer will be customized in the future as a small device so that the projector can embed.

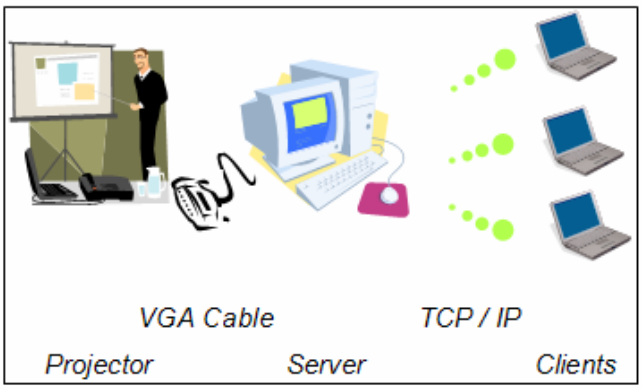

Figure 2. The system architecture

On idle, the server shows a screen that shows an IP address of the computer and how to connect to the server. Each client, such as a PDA, laptop/desktop computers and mobile devices download software and connect to the server through TCP/IP. Once it is connected and the user wants to show her desktop image, client software captures desktop image and sends it to the server every seconds. The server gets image and show it on a projector.

From the HCI perspective, we devised simple user interfaces. Once the software is launched, it is hiding in a system tray. Users click the icon in a system tray with a right mouse button when she wants to share her screen. The software pops up a dialog asking the IP address of the server computer. Once the user enters the IP address, she can share images by just clicking the icon with a left mouse button.

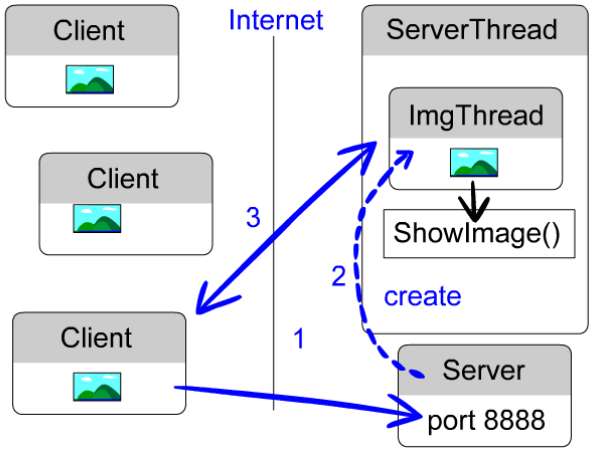

Figure 3. This figure shows how a client-server connection establishes. When the server is up and running, it creates a server thread and listen to port 8888. When a client connects to the server (1), the server creates an image thread (2) that sends and receives the data (3) and shows them on the screen.

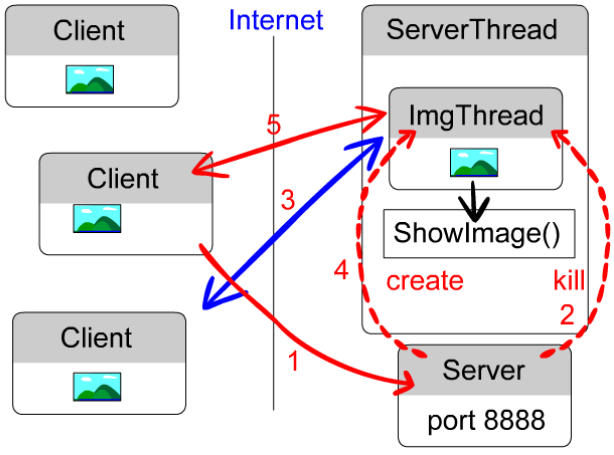

Figure 4. This figure shows how a client creates connection with the server while there's another client connecting to the server. A client is trying to connect to the server through port 8888 (1). The server first kills (2) the previous client (3). After that, it creates a new image thread (4) to communicate with the new client.

The software package can be divided into 2 parts, a server running on the computer attached to the projector, and clients running on the laptops that are going to show screenshots to the projector. The server is a multithreaded program that allows only one thread to receive image data from one client at a time.

Implementation

The software was implemented as a server/client structure. For image processing we used OpenCV libraries. Both client and server-side programs are running as a thread in order to perform multiple tasks. Server-side program opens a socket and waits for a connection from clients. Once a client requests it assign a new socket to the client and receive images and shows it on a projector. The client program is also running as a background process and grabbing desktop image as a JPEG file and sending it to the server.

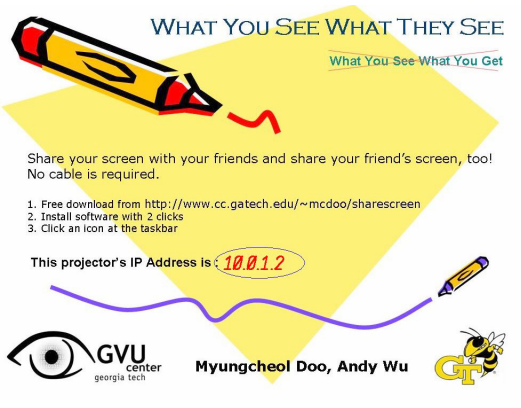

Figure 5. The welcome screen of the software shows the IP address of the server in the middle of the image.

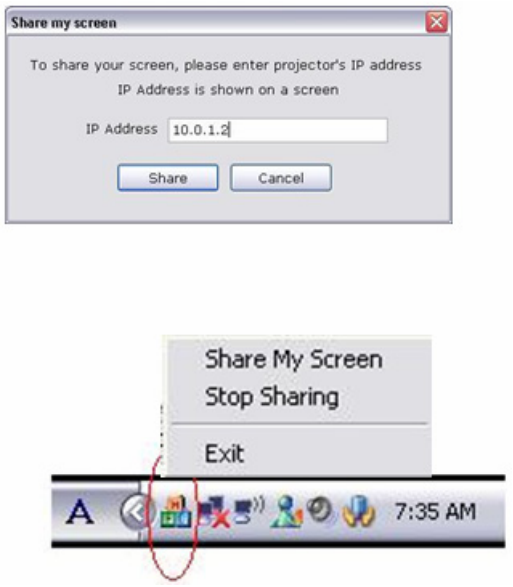

Figure 6. The user can choose the server to connect to.

EVALUATION AND DISCUSSION

The objective of the evaluation plan is to verify if the users prefer to use our software when sharing a projector. Our hypothesis is "users like this software better and this software makes their work more efficient."

Experiment Design

The objective of the evaluation plan is to verify the usability of software when sharing a projector. The user study will be two observations followed by a questionnaire and then a focus group interview. The flow of the study will be:

10 minutes	Introduction; practicing, getting familiar with the software and hardware
20 minutes	Condition 1
5 minutes	Rest time
20 minutes	Condition 1
5 minutes	Questionnaire
20 minutes	Focus group interview

Table 1. The flow of user study.

To interpret the data afterward, we videotaped the observation, and the focus group user study. We expected to recruit 24 subjects and divide them into 6 groups.

When the participants arrive at the schedule time, we introduced the study to participants in detail and ask them to sign the consent form. After that, we give them time to be familiar with the laptops and our software because based on our pilot test; some people don't know how to use a projector.

We design a task of finding 12 photos that are used for creating a photo calendar. The participants have to work collaboratively to accomplish the task. In the test, participants are asked to find 12 photos by themselves on websites such as google.com and flickr.com. For each proposed photo, they have to ask other group members' opinions. In other words, the photo has to be shown to others. Once the other members agree with the photo then the photo is used for the calendar.

The study is a within user test. We recruited four groups and conducted two tests. Each group did the same job, finding photos, twice. In one test, users show their photos by switching a VGA cable. In the other test, they use our software. To avoid order effects, 2 groups performed the task using a traditional cabled projector first while the other 2 groups did the task with our software first.

Figure 7. The control group

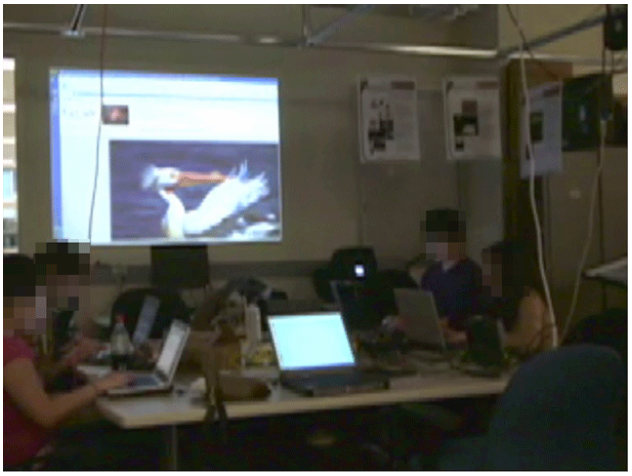

Figure 8. The experimental group

In Figure 7 a girl in pink shirt is passing a VGA cable to the girl in right. So the projector doesn't show anything in this moment. Figure 8 shows people are showing images without any further physical movements.

After the two observation sessions, we gave the participants questionnaires. Table xxx shows the questionnaires. Right after the questionnaire, there was a focus group interview.

Results of User Study

In our pilot run, we found that GT Wireless was not stable. Therefore, we used our own wireless router. Since there were not enough wireless Ethernet cards, some of participants used cable connection to the router. Also some participants have laptop computers while others do not. Thus we use a desktop computer in those cases.

Results of questionnaires

We finally recruited 16 subjects from Georgia Tech campus. Half of the subjects are females. We quantized the questionnaire results by assigning "Totally Disagree" to "Totally Agree" as -2 to +2. We found the average level of agreement is 1.58 and the standard deviation is 0.42. Therefore, we can conclude that the users like our software better. As a result, we verify our hypothesis.

Results of observation

As to the observation, we also measure the time user spent between she initialized the request for the VGA cable and the time she actually showed the image on the projector screen. The average time spent by the subjects is shown in Figure 9. The total time they spent in the study in shown in Table 2.

	Using Cable	Using Software	Improvement
Team 1	17:26 (1046s)	7:25	+57.5%
Team 2	21:30 (1290s)	18:45	+12.8%
Team 3	9:40 (580s)	5:40	+41.4%
Team 4	17:42 (1062s)	20:53	-18.0%

Table 2. The total time spent in the study

Most results show that the software does improve the usage of time. However, team 4 has a totally different result than other teams. The reason is because subjects in team 4 shared more than one photo every time they plugged in the cable. Therefore, they saved a lot of time using cable. We also calculate the percentage of time used in plugging / unplugging the cable (see Table 3). We do not calculate the time of switching between users in the experimental group, since the projector screen was always showing some information and we could not know the time a user initiated a call for sharing photos.

	Showing Image on projector (t1)	t1 / Total Time	Time Spent in plugging Cable (t2)	t2 / t1 (The cost of projecting one second image)	t2 / Total Time
Team 1	8:42 (552s)	52.8%	346s	0.62s	33.1%
Team 2	6:07 (367s)	28.5%	263s	0.71s	20.4%
Team 3	7:56 (476s)	82.1%	214s	0.45s	36.9%
Team 4	3:44 (224s)	21.1%	112s	0.5s	10.5%

Table 3. The total time of projector usage. The cost of projecting one second image means, the time spent on plugging cables to show a one-second image. This table shows how much time the subjects wasted on plugging the cable.

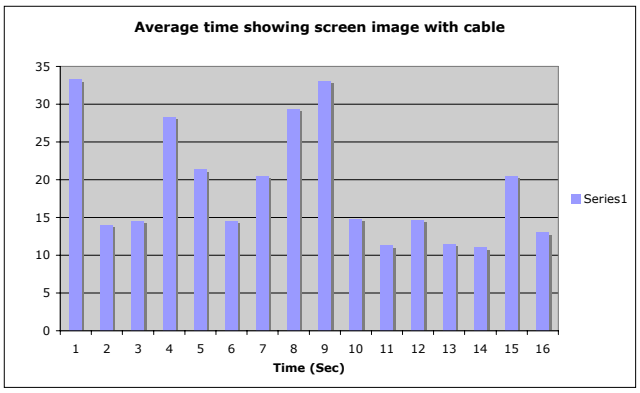

Figure 9. The average time of plugging cable to the projector. 3 samples are dropped because the subjects couldn't show the image to the projector and gave up finally.

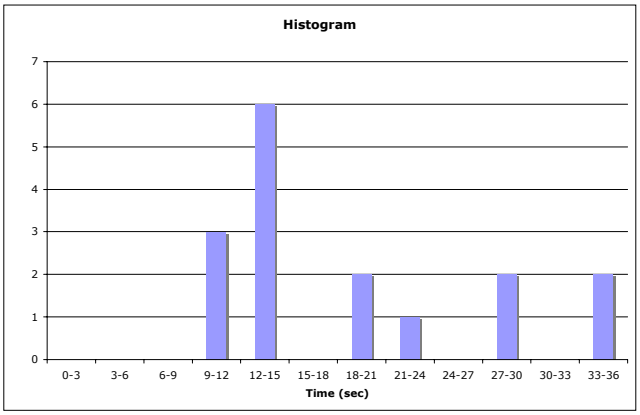

Figure 10. The histogram of average time spent in using cable connection to the projector

We also notice some interesting phenomena of user behaviors:

- Subjects tried to maximize the browser window before they showed it to the projector screen.
- At least 10 subjects were doing other things while the study was processing, e.g. reading emails, news, visiting online stores, chatting on IMs...
- The fish theme made subjects confused. They didn't know that a whale is not a fish, a jellyfish is not a fish, a sea horse is not a fish, a lobster is not a fish, and a dolphin is not a fish.
- Subjects unplugged the cable immediately when they were not using the projector.
- At least 2 subjects pressed the wrong key combination while using the cable and entered the hibernate mode.
- Some subjects couldn't find the cable.
- Subjects help each other pass the cable.
- Some teams decided a photo for each month, and made decision according to the weather of that month while others just chose 12 photos.
- No subjects used the "stop sharing" button. In fact, they all ignored that button.
- During the rest time, some groups kept playing the photo sharing game using the software, but not using the cable.
- One subject forgot she was using the software and looked for the cable.
- One of the subjects kept pressing the wrong hotkey and couldn't switch output to the projector. But she did practice before the study began.
- Subjects walked to those with problem using cables and helped them.
- Since the software delayed for 1 or 2 seconds to show the image, one group negotiated the order of using the software before sharing the screen.

Words from the subjects

We obtained feedbacks that help us understand the subjects' thoughts better from the focus group interviews. This is what they said in the discussion:

- I like this software a lot.
- I hope the software encrypt the image before sending out.
- I want to play video using this software. (The subject had no idea about the frame rate limitation.)
- We seldom use projectors like this way.
- I have to show everything to others, no privacy.
- I don't know who is sharing the screen now. (Using software)
- How about showing two screens on the projected screens?
- This is good for small team discussion.

Discussion

Because we did not have enough wireless cards, some laptops used cables to connect to the router. We found that these laptops have higher priorities over the wireless ones in the experiment of using software. Laptops users using cables can grab the projector screens easier than others. This inequitable condition made the users of wireless laptops frustrated. We saw them shouting and screaming for not being able to share their screens while we conduct the study.

It is interesting that during the user study all subjects were doing some tasks that were not requested. For example, some of them were using IM, browsing news or online

stores or playing a solitaire card game. Whenever they found an interesting image, they showed it after they maximized the browser so that other subjects would not see other applications on the projector screen. One subject showed part of her web mail interface on the projector screen and other subjects started scorning on her for not concentrating on the study.

In the focus group discussion, some subjects actually said that this software is more efficient even though this questioned was mentioned in the questionnaire. Only 4 users used extended desktops in the study. Three of them used it because it was the default setting of the laptop. We prepared laptops for the subjects. But they were not familiar with our laptops and some of the subjects complained about no mouse to use.

Software vs. using Cable

According to our subjects' opinions, we create a table (Table 4.) to compare the advantages and disadvantages. In the table, it seems the disadvantages of this software are more than the disadvantages of using cable. However, most of the listed disadvantages of this software are due to the design of the software rather than the nature of sharing projectors using software. Therefore, it's possible to improve the design in the future.

	Advantages	Disadvantages
Cable	I know who is using I can use extensive desktop Playing videos	Plug/unplug cables Cabled color is wrong How to switch to the projector? I have to reboot my laptop?? Plug and pray
This Software	Just one click Very fast Efficient Distance meeting? Any problem? just re-launch the software	Security Identity Software anyone can grab it Software delay Video may be problematic Privacy

Table 4. The comparison between the two conditions

CONCLUSIONS

We find that users do care about privacy. In the beginning of this research, we considered showing images on a projector screen implies the user is willing to share all information on her screen. However, the study result tells us we need to redesign the software. Also, sharing the whole screen seems not to be the solution to the scenario we mention in the previous paragraph. Since under privacy concern, users want to share only the most important of the information.

Identity

We put the IP address of the laptop using the projector on top of the screen. Obviously, no one noticed that line. Whenever a new image is shown on the screen, they kept asking, "whose screen is that?"

Privacy

We did not consider this issue in the beginning of the study. However, the study results show that users do care about their privacy. During the meeting, they wanted to hide their private work and showed only the information related to the topic. However, it seems people use mirrored display rather than the extended desktop when sharing image because not all of them know how to setup the extended desktop.

Sharing screens vs. sharing information

During the study, one subject tried to show the thumbnails of all photos from the Google image search page. He said, "here are all fish I find, just choose one!" But other subjects thought that was cheating and asked him to stop. We did not interfere this incident. However, we realized one thing, we were assuming that the users wanted to share the whole screen of image, not just some information. There is an anecdote happened in the Ubicomp class, one student found an interesting webpage and wanted to show it to the professor immediately. The professor asked the student to tell him the address so that he could enter it in his laptop, which was connected, to the projector. We considered this was a perfect example of sharing the screen to the projector. However, after the user study, we found that this was not the case we were looking for. The entire student wanted to do is sharing a piece of information. He might be doing his homework of other class, and he would not want others to see that part of screen. In this case, information sharing software is more appropriate than a screen sharing software. They need software that allows users to enter the exact information they want to share other than that shares everything on their own screen.

Research Implications

We think that we should redesign the software to meet a goal. In a group meeting, it is more likely that participants want to share information. In a class environment, which is a more single-person presentation, the speaker wants to share the screen. As a matter of fact, in a single-person presentation, using a software application like this might not be necessary. Unless the speaker is wearing the computer, it is not cool to carry the laptop with this software and walking around in the room. It will be much cooler if the speaker can control the whole flow of the meeting or class by a small remote controller.

Future Work

There are some issues we need to consider in the future; privacy and identification. In order to this, we can use a user ID or an avatar to show the owner of the screen. For privacy issue, we might add a function that can choose specific region to share.

ACKNOWLEDGEMENT

Thanks to Dr. Thad Starner's support so that we can conduct the user study. Also, Jay Summet gave us a lot of advices on software design and user evaluations.

REFERENCES

1. Planex's GW-AP54PR user manual http://www.planex.net/pdf/wireless/GW-AP54PR_Manual_v1.0_Eng.pdf
2. Brad Johanson, Armando Fox, and Terry Winograd, "The Interactive Workspaces Project: Experiences with Ubiquitous Computing Rooms", *Pervasive Computing*, April-June 2002
3. Shahram Izadi, Harry Brignull, Tom Rodden, Yvonne Rogers, Mia Underwood, Dynamo: a public interactive surface supporting the cooperative sharing and exchange of media, In *Proceedings of the 16th annual ACM symposium on User interface software and technology*
4. Foster, G., Stefik, M. Cognoter, Theory and practice of a Colab-orative tool. In *Proc. of the Conference on Computer-Supported Cooperative Work* (CSCW'86). ACM Press. 1986
5. Bier, E.A., Freeman, S. MMM: a user interface architecture for shared editors on a single screen. In *Proc. User Interface Software and Technology* (UIST'91). ACM Press. 1991: p. 79-86.
6. Myers, B.A., Stiel, H., Gargiulo, R. Collaboration Using Multiple PDAs Connected to a PC. In *Proc. on Computer-Supported Cooperative Work* (CSCW'98). ACM Press. 1998
7. Benford, S., et al. Designing Storytelling Technologies to Encourage Collaboration Between Young Children. In *Proc. of Human Factors in Computing Systems* (CHI 2000). ACM Press. 2000